EXPERIMENTATION AND UNCERTAINTY ANALYSIS FOR ENGINEERS, 2ND ED.

By H. W. Coleman and W. G. Steele

John Wiley & Sons, New York; 1999; 269 pages; $69.95.

The subject of properly incorporating uncertainty analysis into experimental programs has been an important topic of discussion in recent years within ASCE overall, and especially within the Water Resources Engineering Division. Most civil engineers have probably had some exposure to the subject through surveying or statistical coursework, and some have surely studied uncertainty analysis in some detail and may already own one or more books on the subject. Even for those already well versed in the subject, the 2nd edition of Coleman and Steele's *Experimentation and Uncertainty Analysis for Engineers* will be valuable reading due to the many recent developments and heightened interest in uncertainty analysis.

The American Society of Mechanical Engineers (ASME), the American Institute of Aeronautics and Astronautics (AIAA), and several other professional organizations have been strong proponents of uncertainty analysis for several years, being ahead of ASCE in this respect. Organizations such as the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI) have promoted standardization of uncertainty analysis procedures. ISO's 1993 publication of the *Guide to the Expression of Uncertainty in Measurement* has essentially established a new international standard for uncertainty analysis. The methodology (but not the complete terminology) of the ISO *Guide* has been adopted in the newly revised ANSI/ASME standard ''Test Uncertainty'' (1998), and in the AIAA standard ''Assessment of Wind Tunnel Uncertainty'' (1995). The adoption of these new standards has produced changes in nomenclature and procedures and has modified the requirements for applying large-sample methods of uncertainty analysis, the most commonly used model. Although ASCE has no formal policy or guidelines on the matter at this time, use of these de facto standards should be encouraged and would be consistent with the *Journal of Hydraulic Engineering's* guidelines for reporting the uncertainty of results from physical experimentation and numerical simulation. This 2nd edition of Coleman and Steele's book has been substantially modified from the book's 1st edition, bringing it up to date with the new standards and incorporating new material on advanced aspects of uncertainty analysis.

The book is divided into two parts. The first four chapters address fundamental statistical concepts and the application of the basic techniques of general uncertainty analysis and detailed uncertainty analysis, used primarily in the planning and design phases of an experimental program. The remaining three chapters address more advanced topics and illustrate their use in the debugging, execution, data analysis, and reporting phases of an experimental program. The focus on the phases of an experimental program and the proper application of uncertainty analysis techniques to each phase is consistent throughout the book. The book is well organized and well written, with concise, clear prose and a relative lack of jargon and acronyms, considering the technical nature of the topic. The book's narrative occupies a slim 234 pages, with an additional 35 pages devoted to three appendices.

The book contains a wealth of example applications incorporated into the narrative, as well as study problems at the end of each chapter. Although the examples are primarily taken from the mechanical engineering spectrum, they are presented with a clarity that makes them easily understood and valuable for those from other backgrounds as well. Several of the examples pertain to hydraulic engineering and fluid mechanics, including a detailed example related to calibration of a venturi flowmeter. The examples focus on the application of uncertainty analysis techniques and emphasize the valuable insight that can be gained through the use of uncertainty analysis.

Coleman and Steele's book is unique, compared with older books that many of today's practicing engineers may own, in that it addresses the estimation and propagation of both precision (random) errors and bias (systematic) errors. Previous approaches have generally assumed that bias errors are reduced to zero through calibration. That assumption is, of course, never true, because calibration standards and procedures are never perfect. In some situations, bias errors can dramatically affect the total uncertainty of a result. Examples illustrate situations in which bias errors are significant, but may be reduced or eliminated using proper experimental design.

Advanced aspects of uncertainty analysis covered in the book's later chapters include the influence of correlated random errors (which have previously been ignored), improved methods of accounting for correlated and/or asymmetric bias errors, determining uncertainties in comparative testing, and dealing with uncertainties associated with digital data acquisition and the dynamic response of test instruments. Other advanced topics include Monte Carlo simulations, regression analyses and proper methods for expressing uncertainty of regression relations, and code validation procedures for use when the result of an experimental program is a comparison of observed performance versus a prediction from a model or computer program. This latter aspect is especially topical, as these days numerous experimental programs are of this type.

There are three appendices to the book. The first appendix

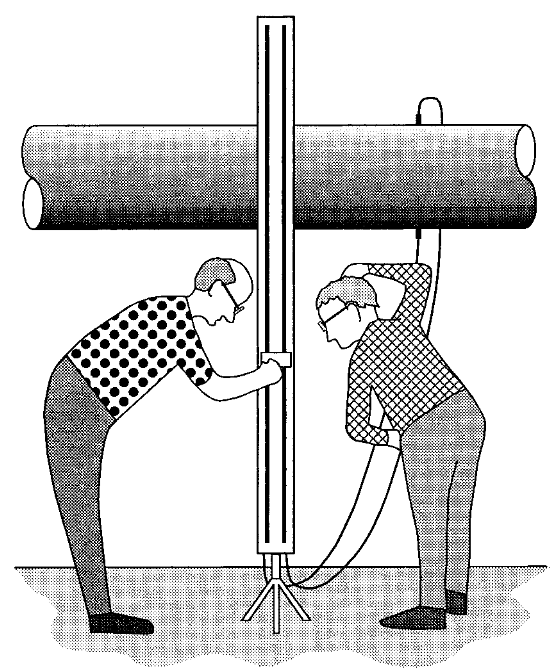

FIG. 1. Are You Sure this Darn Manometer Is Accurate?

provides statistical tables necessary for application of the techniques described in the book. For the interested reader, the last two appendices present the derivation of the primary uncertainty analysis equations and the results of Monte Carlo simulations conducted by the authors to verify the new assumptions that allow applying large-sample uncertainty analysis techniques to experiments with sample numbers as low as 10.

In summary, Coleman and Steele's book should make an excellent reference for all hydraulic engineers seeking to improve the application of uncertainty analysis to their work. Use of the techniques described in the book should lead to more cost-effective research that better answers the questions at hand, while also giving the end user of the work a better understanding of the uncertainty in the final result.

APPENDIX. REFERENCES

''Assessment of wind tunnel data uncertainty.'' (1995). *Standard S-071-1995*, American Institute of Aeronautics and Astronautics, Reston, Va.

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